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Nest Structures and Habitats of the Northern Spotted Owl in Three Ecological Subregions of British Columbia

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F.L. Waterhouse, I.A. Manley,
A.S. Harestad, and P.K. Ott

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EXECUTIVE SUMMARY

Fourteen nest sites of the endangered Northern Spotted Owl (*Strix occidentalis caurina*) in British Columbia were sampled in 2003 and 2004. Nests were located in three broad ecosystem types: the maritime (n = 1), submaritime (n = 6), and continental (n = 7) ecological subregions. Spotted Owls exhibited flexibility in their use of different types of nest structures across their broad ecological distribution. Most nests occurred in chimney top or side cavities of large diameter (average 98 cm dbh) trees and snags (79%) with fewer found on platform type structures (21%). Although a variety of tree species provided nest structures, the largest proportion were Douglas-fir (*Pseudotsuga menziesii*; 79%). There was little evidence that Spotted Owls selected for particular habitat attributes in the immediate area surrounding the nest (patch-level selectivity) within the nest stands, except for higher densities of small trees (< 10 cm dbh) and lower densities of mid-size snags (30–50 cm dbh). Older forest stands (> 140 years old) adjacent to the nest stand were defined as the local landscape. Stand-level selectivity within the local landscape was indicated because nest stands had significantly taller trees than adjacent stands. Nest stands were not uniformly distributed across available aspects (10–290°); most (92%) were on southerly and or eastern aspects, but the importance of aspect within the broader regional landscape is unknown. Findings from our study using a small sample of Northern Spotted Owl nest sites in British Columbia appear consistent with those from studies in the United States. The findings of our study support provisioning for nesting habitat over the long term, as undertaken in the current Spotted Owl Management Plan (SOMP2).

Key Words

Northern Spotted Owl, *Strix occidentalis caurina*, nest site, nest structure, nest habitat, British Columbia, Spotted Owl Management Plan

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INTRODUCTION

The northernmost part of the range of the Northern Spotted Owl (*Strix occidentalis caurina*; hereafter Spotted Owl) occurs on the southwest mainland of British Columbia; it extends southward through Washington and Oregon to northern California (Chutter et al. 2004). Loss of the Spotted Owls' preferred habitat—structurally complex old forest—due mostly to logging and urbanization, has contributed to its current "Endangered" status in Canada (Chutter et al. 2004). Structurally complex old forest is preferred by Spotted Owls because it supplies suitable potential nest structures (i.e., side or top cavities or platforms for nests), higher densities of small mammal prey, perches for hunting and roosting, and an open subcanopy for flight (reviewed in Chutter et al. 2004; Courtney et al. 2004), in contrast to conditions found in comparatively younger forests. Spotted Owls show strong fidelity for their selected breeding habitats (Forsman et al. 1984).

Recent management efforts in British Columbia to recover the Spotted Owl include:

1. a revised Spotted Owl Management Plan (SOMP2) that reconfigured previously identified owl management areas into Long-term Owl Habitat Areas (LTOHA) and Managed Future Habitat Areas (MFHA), including modified operational resource practices (Government of British Columbia 2010; B.C. Ministry of Environment 2011); and
2. a captive breeding-release program (SOPET 2007).

The success of both these actions requires an understanding of Spotted Owl nesting habitat in British Columbia, but most habitat information for the Northern Spotted Owl comes from studies in Washington, Oregon, and California (reviewed in Courtney et al. 2004). This information is often extrapolated to guide management of Spotted Owls in British Columbia (reviewed in Sutherland et al. 2007, 2010). However, by using a small sample of nest sites located in British Columbia, we now have the opportunity to directly evaluate nesting habitat information used to guide management.

In British Columbia, 16 nest sites have been located since 1985 (B.C. Conservation Data Centre 2011). Manley et al. (2004) compiled habitat information for 11 of the nest sites and examined habitat selection for these nest sites with respect to two characteristic biogeoclimatic zones: the Coastal Western Hemlock (CWH) and the Interior Douglas-fir (IDF) (Meidinger and Pojar [compilers and editors] 1991). For this report, we used the sample of nest sites reported by Manley et al. (2004) and added three more sites to increase the sample to 14 nests. Additionally, we used a different approach to classify the sites, in this case aligning the sites with three broad ecological subregions currently used to guide management of Spotted Owl habitats and based on subzone variants of the CWH and IDF zones (Sutherland et al. 2007, Appendix 3). The objectives of our analyses are (1) to describe 14 of the 16 known nest structures, nest patches, and nest stands relative to the ecological subregions in which they occur; (2) to test for habitat selection within the nest stand (patch-level) and within the local landscape that we defined as the area containing the forest nest stand and forest stands greater than 140 years old adjacent to it (stand-level) relative to the ecological subregions; and (3) to

evaluate how local British Columbia nesting habitat information was incorporated into interpreting "Superior" owl habitat for SOMP2. In this study, habitat selectivity is defined as significant if there is proportionately greater use (or avoidance) of a habitat feature or condition compared to its availability (Manly et al. 2002).

STUDY AREA

The range of the Spotted Owl in British Columbia extends north from the U.S. border to include portions of both the Coast and Cascade Mountain ranges (Chutter et al. 2004). The nests were located in stands of predominantly older forest (> 200 years) and distributed among three ecological subregions. The three ecological subregions as described by Sutherland et al. (2007) transition from wetter maritime subzone variants of the CWH zone to drier interior continental subzone variants of the IDF zone (Mitchell et al. 1981; Green and Klinka 1994). These subregions are the maritime (wetter), submaritime (drier), and continental (driest) with subzone variants of both the CWH and IDF zones occurring in the submaritime. Owl nests were distributed among the ecological subregions and subzone variants as follows: maritime (n = 1 in the Submontane Very Wet Maritime CWH variant, CWHvm1); submaritime (n = 3 in the Southern Dry Submaritime CWH variant, CWHds1, and n = 3 in the Wet Warm Interior Douglas-fir variant, IDFww); and continental (n = 6 in the Dry Cool Interior Douglas-fir variant, IDFdk02, and n = 1 in the Very Dry Cold Interior Douglas-fir, IDFxc).

METHODS

Field Site Sampling

Nest and nest structure Nests used in the analyses were found between 1985 to 2003 and found incidental to detection inventories for Spotted Owls. Areas inventoried and inventory methods (including nest search efforts) varied in any one year to meet different management objectives (Sutherland et al. 2010; J. Hobbs, B.C. Ministry of Forests, Lands and Natural Resource Operations, pers. comm., Jan. 2012). Nests were classified by type: chimney top cavity of broken snag or tree, branch side cavity of live tree, stick nest built by previous occupant, or Douglas-fir dwarf mistletoe (*Arceuthobium douglasii*) on the tree. The following information was recorded for each nest structure: tree species, diameter at breast height (dbh), and appearance of each structure supporting the nest based on a wildlife tree classification scheme (Luttmerding et al. [editors and compilers] 1990). Attributes related to the nests' spatial location within the forest (height of the nest above ground, relative height of the nest to the structure in which it occurred, and relative height of the nest to the overstorey forest canopy) and the broader local landscape (elevation, slope, and aspect) were recorded as well.

Habitat patch Habitat attributes of the immediate area surrounding and influencing the nest structure (i.e., the patch) were sampled using nested 7.98-m radius (0.02 ha) and 25-m radius (0.19 ha) plots centred on the nest structure. All plots were measured using slope-corrected distances. All cover

estimates were visual and the average of two observers (Luttmerding et al. [editors and compilers] 1990). Vegetation cover estimated within the 7.98-m radius plot included the percentage of ground covered by a vertical projection of the crown of plants onto the surface for tree overstorey co-dominant canopy, shrubs of 0.15–1.99 m (B1 layer) and > 0.20 m height (B2 layer) classes, total vegetation including shrubs and seedlings < 0.15 m, and all herbs and ferns. Percentage of ground cover was estimated for the horizontal surface and included estimates for moss/lichen, decaying wood, rock, water, and organic matter. Observers classified forest structural stage using the 25-m radius plot according to five general development stages: shrub, pole/sapling, young forest, mature forest, and old forest (Luttmerding et al. [editors and compilers] 1990). The plot was assigned the lowest (i.e., youngest) structural stage if the field review indicated two classes. Also, using the 25-m radius plot, all trees > 0.15 m height and snags ≥ 10 cm dbh in the plot were counted, species recorded, and diameters measured if ≥ 10 cm dbh.

Coarse woody debris (CWD) was assessed by data collected along two 25-m radial transects. The first transect was established on a random bearing originating from the nest tree and the second was located at 90° clockwise from the first. Diameters, angles (degree), and decay classes (Hard = intact/hard, Moderate = partly decayed, Soft = blocky / well decayed) of pieces > 7.5 cm dbh that were crossed by the transect lines were sampled (British Columbia Ministry of Forests (MOF) and British Columbia Ministry of Environment Lands and Parks (MELP) 1998) and volume (m^3/ha) of each piece was calculated based on Huber's formula (Marshall et al. 2000).

Random patch For determining if particular forest structure attributes were selected for at the nest site within the nest stand (patch-level selectivity), each nest patch was paired with a random patch situated in the same forest stand. Nest stand boundaries were defined as those shown on 1: 20 000 Government of British Columbia forest cover maps available at the time of sampling. Forest stands (i.e., also referred to as polygons) on these maps are in general delineated using a minimum map unit of 5 ha and defined as those areas of contiguous forest of similar tree species composition, age, height, and crown closure as interpreted from aerial photographs and standardized by ground verification inventory plots (RIC 2003). Random patches were established by taking a random azimuth from each nest tree and going a random distance selected between 60 and 100 m to locate a random point. The minimum distance (60 m) ensured that the random plot would not overlap the nest plot, while the maximum distance (100 m) was set to ensure that the random plot retained site characteristics (aspect, elevation, and slope) of the local nest area that could otherwise vary in large forest stands. The canopy tree (> 30 cm dbh) or snag (> 2 m height, > 30 cm dbh) nearest to the random point was used as the "random" pseudo-nest structure on which the random patch was centred.

Air Photo Sampling

We defined the local landscape available to the Spotted Owl for nesting as the area that included the nest stand and stands of forest adjacent to it that were greater than 140 years old. Stands greater than 140 years old were only considered as part of the local nesting landscape because Spotted Owls are thought to not use younger stands for nesting (SOMIT 1997; Chutter et al. 2004). For determining if forest stands with particular features were selected for nesting within the local landscape (stand-level selectivity), we randomly

selected one of the greater than 140-year-old stands adjacent to the nest stand and paired it with the nest stand. To do this, an air photo interpreter first used standard classification methods and delineated the nest stand and stands adjacent to it directly on 1:15 000 scale air photos (i.e., aerial photographs) of the nearest available date to the year the nest was found (RIC 2003). Second, the air photo interpreter then estimated the average stand attributes of the nest stands and the paired random stands. Attributes measured included species composition, average tree height (m), average crown closure (%), basal area (m^2/ha), and vertical complexity class (RIC 2003, Appendix A). By having the air photo interpreter directly assess the air photos to confirm mapped polygons and estimate attribute values, we limited potential bias because air photo interpretation is qualitative. This process replaces relying on existing forest cover maps that were created by multiple interpreters and potentially had attribute estimates adjusted using regional ground plots.

Analyses

Comparisons were made between ecological subregions and/or between nest and random patches within nest stands. For all tests we considered $\alpha = 0.10$ as our level of significance due to the exploratory nature of the analyses combined with a small sample size that likely made potential differences more difficult to detect. Statistical analyses were conducted using SAS 9.1.3 (SAS Institute Inc. 2004).

Characterizing nesting habitat Summary statistics of characteristics of nest trees and attributes of nest and random patches and stands were reported by ecological subregion and pooled across ecological subregion for comparisons with values used for Best Management Practices (BMPs) in Spotted Owl areas (Government of British Columbia 2010). Differences among continuous nest tree attributes between two ecological subregions (Subregion: submaritime and continental) were tested using two-sample randomization tests based on the t statistic (Manly 1997; Good 2005). Analyses were not conducted for the maritime ecological subregion because of the single nest sample. A Watson one-sample U^2 test (Zar 1984) was used to determine if the aspects of nest stands were uniformly distributed. Although aspect data were collected at both nest and random sites, because the estimates were similar (i.e., 12 of 14 pairs of sites had values that were within 30°, while the other two differed by 40° and 60°) and at a scale that reflected the general slope of the stand containing both the nest sites and random sites, rather than within-stand differences, only the nest site estimates were analyzed for aspect distribution.

Testing for habitat selectivity Selectivity for habitat attributes described by continuous and ordinal variables was tested using a completely randomized split-plot design with Subregion (continental or submaritime) as the main plot factor and Patch Type (nest or random patches) as the split-plot factor. The single maritime sample was excluded. Elevation and slope were not tested for Patch Type because these attributes were constrained by occurring within the same stands, and differences at that scale were not expected. Due to the small sample sizes and the potential non-normality of the data, randomization (permutation) tests were used in lieu of traditional ANOVA F-tests (Manly 1997; Good 2005). Selectivity for stand structural stage, a categorical variable, was also tested using randomization, but based on the appropriate Chi-square statistics from a loglinear model.

The randomization tests compare the observed test statistic with the distribution of values obtained after the observations are repeatedly randomly allocated to the different levels of the two factors. Under a null hypothesis of no Subregion or Patch Type effect, the observed test statistic should not differ significantly from those values generated from the random assignment of Subregion or Patch Type. An unusually large observed test statistic relative to the statistics from the randomized reference distribution is evidence that the null hypothesis is unlikely.

Due to the split-plot design, the randomization process actually involved three parts:

1. Subregion was tested by randomly allocating 6 pairs to the submaritime and 6 to the continental group, resulting in $12!/(6!6!) = 924$ possible combinations for the reference distribution.
2. Patch Type was tested by randomly assigning the two Patch Type labels (nest and random) within each of the 12 pairs, resulting in $2^{12} = 4096$ potential combinations.
3. The Subregion × Patch Type interaction was tested by randomly allocating pairs to Subregion and Patch Type labels within each pair simultaneously, resulting in $924 \times 4096 = 3\,784\,704$ potential combinations. If significant interactions between Subregion and Patch Type were detected, the Patch Type effect within each Subregion was tested separately. With 6 pairs per Subregion, there are $2^6 = 64$ possible combinations for each of these reference distributions.

Air photo variables were similarly tested, where paired adjacent stands (in this case n = 13 pairs) within the local landscape were nested in one of the two ecological subregions. All tests were based on 9999 randomizations, and conducted using a SAS 9.1.3 program involving Proc Mixed or Proc Genmod (SAS Institute Inc. 2004). Only the observed test statistic and the least-square means (standard errors) for significant tests ($P \leq 0.10$) are presented.

RESULTS

Characteristics of Nests and Nest Trees

Nest structures and nest sites Nests of Spotted Owls were located in both live and dead trees (snags) and were supported by four types of structures including cavities (top and side) created from breakage and decay and platforms created by Douglas-fir dwarf mistletoe and abandoned Northern Goshawk (*Accipiter gentilis*) stick nests (Table 1a). Dead trees made up 43% (6 of 14) of the nest tree sample and all had chimney top cavities, the most common type of nest structure (Table 1a). Some chimney top cavities (25%; 2 of 8) as well as the other types of nest structures occurred in live trees. Nest structures were predominantly associated with Douglas-fir (*Pseudotsuga menziesii*), although cavities in western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) were also used (Table 1a).

Nest structures had on average large diameters (Table 1b). The average diameter of the 11 cavity nest structures was 97.8 cm (SD 21.0) dbh. The two trees with stick nests averaged 49.5 cm (SD 0.8) dbh and were similar in size to the tree that supported the mistletoe nest (57.5 cm dbh). Despite submari-

time nest sites having significantly taller overstorey canopies than continental nest sites (Table 2), the vertical positioning of nests was similar across ecological subregions. Nests were usually located within the upper third of the nest structure (nest height/tree height; Table 1b), but beneath or in the lower overstorey canopy (nest height/canopy height; Table 1b).

TABLE 1a *Proportion of attributes of 14 Spotted Owl nest trees in three broad ecological subregions of southwestern British Columbia*

Attribute	Ecological subregion			
	Maritime n = 1 Percentage (%)	Submaritime n = 7 Percentage (%)	Continental n = 6 Percentage (%)	Total n = 14 Percentage (%)
Nest type				
• Chimney top cavity	0	57	67	57
• Branch side cavity	100	29	0	21
• Mistletoe platform	0	14	0	7
• Stick platform	0	0	33	14
Tree species				
• Douglas-fir	0	86	83	79
• western hemlock	100	0	0	7
• western redcedar	0	14	0	7
• black cottonwood	0	0	17	7
Appearance				
• 1 = live tree	100	43	50	50
• 2 = declining tree	0	14	0	7
• 6 = broken top snag	0	29	17	21
• 7 = decaying broken top snag	0	14	33	21

TABLE 1b *Averages of attributes of 14 Spotted Owl nest trees in three broad ecological subregions of southwestern British Columbia*

Attribute	Ecological subregion			
	Maritime n = 1	Submaritime n = 7 Average (SD)	Continental n = 6 Average (SD)	Total n = 14 Average (SD)
Overstorey canopy height (m)	55.0	39.0 (8.6)	27.8 (2.7)	35.4 (10.0)
Nest tree diameter (dbh cm)	98.6	98.3 (26.6)	74.3 (25.0)	88.0 (26.8)
Live tree height[a] (m)	46.5	35.2 (8.6)	28.6 (2.0)	34.1 (8.3)
Dead tree height[b] (m)	–	13.8 (3.4)	9.8 (5.3)	11.8 (4.5)
Live tree nest height[a] (m)	38.0	18.6 (1.1)	15.5 (3.4)	19.9 (7.7)
Dead tree nest height[b] (m)	–	12.6 (3.8)	9.8 (5.3)	11.2 (4.4)
Nest height/tree height (%)	82	72	77	77
Nest height/canopy height (%)	69	43	46	45

a Only a subset of nest trees was alive: Maritime n = 1, Submaritime n = 4, Continental n = 3.
b Only a subset of nest trees was dead: Submaritime n = 3, Continental n = 3.

Nest stands, although distributed over a broad range (10–290°) of aspects, were not uniformly distributed (n = 13, $U^2 = 1.31$, $P < 0.05$) with most facing south and/or east aspects: 7 southeast, 3 northeast, 1 northwest, and 2 southwest. Relative to the surrounding landscapes, nest sites on average occurred at mid elevations (e.g., ~ average 700 m, range 368–875 m; Table 3) and on moderate slopes (e.g., ~ average 50%, 0–70%; Table 3). Elevations of nest

stands differed significantly between the submaritime and continental, with used locations generally occurring at higher elevations in the continental compared to the submaritime (~ 200–300 m average difference; Table 2).

TABLE 2 *Habitat attributes with significant (P ≤ 0.10) non-parametric randomization tests for evaluating differences between Subregion (submaritime and continental) and Patch Type with paired Spotted Owl nest and random plots. Least-square means (LSmeans) and standard errors (SE) are reported for significant tests of these habitat attributes.*

Attribute	Subregion F / P[a, b]	Patch Type F / P[a, b]	Submaritime LSmeans (SE)	Continental LSmeans (SE)	Nest LSmeans(SE)	Random LSmeans(SE)
Canopy height[c] (m)	9.14*	N/A	39.0 (2.5)	27.8 (2.7)		
Elevation[d] (m)	5.00*	1.25	572.9 (91.8)	863.3 (91.8)		
Height (m)	3.19	5.60*	34.1 (2.0)	28.9 (2.15)	32.7 (1.5)	30.3 (1.5)
Moss (%)	2.97*	0.00	20.8 (8.0)	1.3 (8.1)	11.1 (5.9)	11.0 (5.9)
Conifers < 10 cm dbh (per plot)	3.30*	2.62	95.6 (26.5)	27.5 (26.5)	76.9 (21.0)	46.2 (21.0)
Trees < 10 cm dbh (per plot)	3.97*	2.98*	117.2 (25.6)	44.9 (25.6)	98.4 (20.7)	63.7 (20.7)
Trees 10–30 cm dbh (per plot)	3.93*	0.47	63.3 (8.4)	39.8 (8.4)	47.9(7.9)	55.1 (7.9)
Trees ≥ 76 cm dbh (per plot)	7.10*	1.75	7.7 (1.4)	2.5 (1.4)	6.3(1.4)	3.8 (1.4)
Trees ≥ 10 cm dbh (per plot)	3.19*	0.70	93.9 (9.8)	69.1 (9.8)	76.7(9.0)	86.3 (9.0)
Snags 31–50 cm dbh per plot	1.23	3.13*	1.9 (1.1)	3.6 (1.1)	1.5 (1.0)	4.0 (1.0)
CWD < 30 cm dbh (m^3/ha)	4.22*	0.03	37.3 (9.8)	65.8 (9.8)	50.4 (9.6)	52.8 (9.6)

a A * indicates significant P ≤ 0.10.
b Degrees of freedom = 1, 10 except for Elevation and Height = 1, 11 and Moss 1, 9.
c See analyses methods. Subregion only test was using a Chi-square test and degrees of freedom = 1.
d Elevation not tested as constrained within same stand.

Nest patches and nest stands Few significant differences between nest and random patches within the nest stand and few differences between ecological subregions were found using the randomization tests for the tested forest structural attributes (Tables 3–5). For cover estimates a significant interaction between Subregion and Patch Type ($F_{1, 6} = 3.69$, P = 0.10) occurred for rock cover and was likely due to low rock cover at the three continental random sites (Table 3). However, Patch Type did not significantly differ (P > 0.10) when rock cover was tested separately within each Subregion. The only other difference determined for cover estimates of structure was that average coverage of moss was significantly greater in the submaritime compared to the continental (Table 2).

Forest structure defined by densities of trees and snags differed within stands of both ecological subregions where significantly higher densities of small (< 10 cm dbh) trees, but lower densities of mid-size (31–50 cm dbh) snags occurred in nest patches compared to random patches (Table 2). Yet ecological subregions differed where overall patches in the continental had significantly fewer small-diameter trees (< 10 and 10–30 cm dbh), large diameter (≥ 75 cm dbh) trees, and total trees (≥ 10 cm dbh) compared to those in

TABLE 3 *Characteristics of 14 Spotted Owl nest sites and 13 random sites among broad ecological subregions described using 0.02-ha (7.98-m radius) plots. Random plot data were not available for most attributes in the Maritime.*

	Ecological subregion							
	Maritime		Submaritime		Continental		Total	
Patch type attribute	Nest n = 1	Random n = 1	Nest n = 7 Average (SD)	Random n = 6 Average(SD)	Nest n = 6 Average (SD)	Random n = 6 Average (SD)	Nest n = 14 Average (SD)	Random n = 13[a] Average (SD)
Canopy closure (%)	60	50	47.9 (21.8)	59.2 (12.4)	42.5 (21.9)	36.7 (18.6)	46.4 (20.6)	48.1 (18.3)
Shrub (%)	55	-	44.3 (14.3)	49.2 (20.1)	55.8 (15.6)	49.2 (21.5)	50.0 (14.9)	49.2 (19.9)
Shrub B1 (%)	40	-	39.0 (23.6)	26.8 (21.7)	51.8 (30.2)	32.7 (18.6)	44.6 (25.5)	29.8 (19.5)
Shrub B2 (%)	71	-	31.1 (21.9)	27.7 (17.4)	22.7 (13.3)	21.2 (22.9)	30.4 (21.1)	24.4 (19.7)
Vegetation (%)	45	-	18.1 (28.7)	20.0 (12.7)	16.7 (31.6)	18.0 (17.8)	19.4 (28.6)	14.0 (15.2)
Moss (%)	6	-	27.9 (33.9)	20.8 (25.6)	1.3 (2.0)	1.4 (2.1)	14.9 (26.7)	12.0 (20.8)
Organic matter[b] (%)	0	-	23.4 (24.7)	37.0 (27.3)	35.8 (37.9)	54.0 (38.3)	27.1 (30.5)	43.4 (30.4)
Decaying wood[b] (%)	60	-	30.7 (16.4)	25.0 (17.0)	20.8 (8.0)	25.0 (22.9)	28.6 (16.0)	25.0 (17.7)
Rock[b] (%)	15	-	31.6 (33.0)	33.0 (24.4)	36.0 (30.3)	16.0 (21.2)	32.0 (29.7)	26.6 (23.4)
Water (%)	0	-	0	0	0	0	0	0
Elevation (m)	599	611	531 (251)	565 (243)	867 (196)	860 (227)	679 (269)	705 (262)
Slope (%)	65	60	49 (21)	40 (19)	50 (25)	53 (27)	50 (21)	48 (22)

a Totals include random maritime; n = 13.

b Only a subset of random sites had this attribute: submaritime random n = 5 and continental random n = 3.

TABLE 4 *Density of trees and snags (stems/ha) averaged by Ecological Subregion and Patch Type (nest and paired random site) within Spotted Owl nest stands. Totalled averages across ecological subregions are presented. Averages are not adjusted to reflect the sample used for testing for statistical differences.*

	Ecological subregion							
	Maritime		Submaritime		Continental		Total	
Patch type attribute	Nest n = 1	Random n = 1	Nest Average (SD) n = 7	Random Average (SD) n = 6	Nest Average (SD) n = 6	Random Average (SD) n = 6	Nest Average (SD) n = 14	Random Average (SD) n = 14
Trees (cm dbh class)								
• conifer < 10	1201.9	555.1	567.5 (567.5)	359.9 (302.1)	169.8 (285.9)	110.3 (92.8)	442.4 (516.9)	259.7 (255.1)
• deciduous < 10	0	0	117.1 (107.2)	82.3 (84.0)	82.3 (80.6)	95.1 (118.0)	93.9 (94.0)	82.3 (96.9)
• total < 10	1201.9	555.1	684.6 (568.3)	443.1 (256.4)	252.1 (303.5)	205.4 (161.2)	536.2 (517.44)	342.0 (237.6)
• 10–30	213.9	147.7	290.3 (131.6)	351.4 (162.8)	195.2 (128.3)	209.7 (117.7)	244.1 (129.0)	270.3 (152.3)
• 31–50	50.9	56.0	58.9 (21.0)	91.7 (63.9)	91.7 (70.2)	118.8 (70.2)	72.4 (49.0)	101.5 (58.9)
• 51–75	25.5	45.8	42.9 (23.7)	38.2 (24.3)	35.7 (28.1)	24.6 (22.4)	38.6 (24.3)	32.8 (22.7)
• ≥ 76	40.7	35.7	42.9 (25.1)	32.3 (25.5)	18.7 (29.1)	6.8 (10.0)	32.4 (27.7)	20.8 (22.2)
• ≥ 51	66.2	81.5	85.9 (36.7)	70.5 (18.6)	54.3 (51.4)	31.4 (29.9)	70.9 (43.4)	53.3 (31.2)
• ≥ 31	117.1	137.5	144.8 (39.5)	162.1 (68.0)	146.0 (58.7)	150.2 (87.1)	143.3 (45.9)	154.7 (71.7)
• ≥ 10	331.0	285.2	435.1 (516.9)	516.9 (213.3)	341.2 (362.4)	362.4 (134.1)	387.4 (131.0)	427.8 (185.1)
Snags (cm dbh class)								
• 10–30	10.2	5.1	32.0 (25.6)	50.1 (50.5)	34.0 (37.5)	44.1 (17.2)	31.3 (29.7)	43.9 (36.5)
• 31–50	5.1	10.2	5.1 (4.2)	14.4 (28.5)	10.2 (7.2)	26.3 (21.0)	7.3 (5.9)	19.6 (23.8)
• 51–75	10.2	10.2	5.9 (7.5)	2..5 (4.3)	7.6 (11.9)	5.9 (2.1)	7.1 (9.2)	4.7 (3.9)
• ≥ 76	15.3	15.3	4.4 (5.4)	0.8 (2.1)	5.1 (5.6)	5.9 (12.5)	5.5 (5.8)	3.9 (9.1)
• ≥ 51	25.5	25.5	9.5 (8.5)	3.4 (4.2)	12.7 (16.0)	11.0 (12.2)	12.0 (10.1)	8.6 (10.5)
• ≥ 31	30.6	35.7	14.6 (9.0)	17.8 (32.2)	22.9 (11.5)	37.7 (23.2)	19.3 (12.8)	28.2 (27.5)
• ≥ 10	40.7	40.7	46.6 (33.3)	67.9 (79.1)	56.9 (39.0)	83.2 (23.4)	50.6 (33.6)	72.9 (54.7)

TABLE 5 *Volume of coarse woody debris (m^3/ha) summarized by decay class (soft, medium, hard) and by diameter class as averaged by Ecological Subregion and Patch Type (Spotted Owl nest and paired random site within the stand). Averages are not adjusted to reflect the sample used for testing for statistical differences. The Maritime ecological subregion was not sampled for coarse woody debris.*

	Ecological subregion					
	Submaritime		Continental		Total	
Patch type attribute	Nest Average (SD) n = 7	Random Average (SD) n = 6	Nest Average (SD) n = 6	Random Average (SD) n = 6	Nest Average (SD) n = 13	Random Average (SD) n = 12
Diameter						
• Total	149.7 (128.4)	315.7 (306.0)	163.4 (156.7)	202.5 (157.7)	156.0 (136.1)	259.1 (197.7)
• Small (< 30 cm dbh)	37.2 (40.0)	36.7 (29.7)	62.7 (25.5)	68.9 (31.7)	49.0 (35.3)	52.8 (67.5)
• Medium (30–50 cm dbh)	49.6 (72.6)	59.6 (114.2)	39.9 (52.8)	55.9 (73.2)	45.1 (61.9)	57.8 (142.1)
• Large (> 50 cm dbh)	62.9 (67.6)	219.4 (209.3)	60.8 (115.8)	77.7 (93.5)	61.9 (88.7)	148.6 (147.6)
Decay						
• Hard (Classes 1 and 2)	18.9 (24.2)	100.4 (159.3)	42.5 (39.6)	42.0 (30.8)	29.8 (33.1)	71.2 (105.4)
• Moderate (Class 3)	98.2 (112.6)	63.9 (108.2)	18.7 (21.1)	62.5 (104.7)	61.5 (90.7)	63.2 (132.4)
• Soft (Classes 4 and 5)	32.6 (60.0)	151.4 (191.6)	102.2 (160.9)	98.0 (122.5)	64.7 (117.9)	124.7 (155.8)

the submaritime (Table 2). A significant interaction between Subregion and Patch Type was detected for small deciduous trees ($F_{1, 10} = 4.64$, $P = 0.07$) because nest patches appeared to have higher densities in the submaritime, but lower densities in the continental when compared to the random patches. Differences in densities of small deciduous trees were non-significant ($P > 0.10$) when Patch Type was tested separately within each Subregion. The only significant difference in volume of CWD was between ecological subregions because small coarse woody debris (CWD < 30 cm dbh) occurred in greater volumes in the continental compared to the submaritime (Table 2).

Most nest patches were classified as being in the structural stage characterized as old forest (Table 6). Although the classification of nest and random patches within the nest stand did not differ significantly ($P > 0.10$), of the five pairs that differed in class, all nest patches were classed as old, while random patches were classed as mature (n = 4) or young (n = 1).

Tree species composition in nest stands varied by ecological subregions although most had Douglas-fir as one of the leading species used to define tree composition of the stand (RIC 2003). An exception was the maritime nest stand comprised of western hemlock, amabilis fir (*Abies amabilis*), and western redcedar. All nest stands in the submaritime had a component of Douglas-fir (60–100%) combined with small amounts (10–20%) of western redcedar, western hemlock, or pine (*Pinus* sp.). Continental nest stands similarly had 60–100% Douglas-fir and components of spruce (*Picea* sp., 20–30%) and/or pine (10–20%); the one exception being a stand located on a floodplain that was dominated by black cottonwood, spruce, and western redcedar.

Few habitat attributes described by air photo interpretation for the nest and adjacent random stands differed by Subregion or Stand Type (Table 7).

TABLE 6 *Structural stage of 14 Spotted Owl nest sites and 13 random sites among broad ecological subregions described using 0.19-ha plots*

	Ecological subregion							
	Maritime		Submaritime		Continental		Total	
Patch type	Nest n = 1 Percentage (%)	Random n = 1 Percentage (%)	Nest n = 7 Percentage (%)	Random n = 6 Percentage (%)	Nest n = 6 Percentage (%)	Random n = 6 Percentage (%)	Nest n = 14 Percentage (%)	Random n = 14 Percentage (%)
Structural stage[a]								
• 5 ≡ young	0	0	0	17	0	0	0	8
• 6 ≡ mature	0	0	29	33	33	83	39	54
• 7 ≡ old	100	100	71	50	67	17	71	38

a Totals include random maritime; n = 13.

TABLE 7 *Air photo habitat variables described for 14 Spotted Owl nest stands by Ecological Subregion and for 14 paired random adjacent stands (Stand Type)*

	Ecological subregion							
	Maritime		Submaritime		Continental		Total	
Stand type variable	Nest n = 1	Random n = 1	Nest Average (SD) n = 7	Random Average (SD) n = 7	Nest Average (SD) n = 6	Random Average (SD) n = 6	Nest Average (SD) n = 14	Random Average (SD) n = 14
Crown closure (%)	60	60	56.4 (6.3)	46.4 (14.9)	56.7 (6.8)	60.8 (12.8)	56.7 (6.1)	53.6 (14.9)
Height (m) 30.9 (6.2)	46	36	35.4 (3.6)	32.9 (5.0)	30.0 (6.3)	27.8 (7.0)	33.9 (6.4)	
Basal area (m^2/ha) 55.7 (19.1)	75	65	66.4 (15.2)	57.9 (19.3)	55.8 (13.2)	51.7 (21.4)	62.5 (14.6)	
Vertical complexity								
• Uniform	0	0	0	14	0	0	0	0
• Moderately uniform	100	100	57	29	67	100	64	64
• Non-uniform	0	0	14	57	33	0	21	29
• Very non-uniform	0	0	29	0	0	0	14	7

Stand height significantly differed, indicating that nest stands had taller trees compared to adjacent random stands (Table 2). Although crown closure estimates were similar for nest stands in both Subregions, adjacent random stands had lower estimates than nest stands in the submaritime, but higher in the continental, resulting in a significant interaction between Subregion and Stand Type ($F_{1, 10} = 4.54$, $P = 0.06$). Differences in Stand Type were non-significant when tested separately by Subregion.

Comparison to SOMP2

We compared the values of habitat attributes measured in our study with "Superior" values defined under SOMP2 BMPs (Table 8; Government of British Columbia 2010). Comparisons include only the maritime and submaritime because, under SOMP2, timber harvest (including mainline road construction) is not allowed in some owl management areas (Wildlife Habitat Areas) and these particular areas all happen to overlap the continental. Hence "Superior" attributes values were not defined in the BMPs for the continental (Government of British Columbia 2010). We found that average attribute estimates for nest stands mostly fall within the ranges of those recommended for "Superior" owl habitat under SOMP2. Yet, potential differences between the sampled nest habitat and the Superior definition were indicated based on the tree density averages and the crown and canopy closure averages, with the sampled nest habitat tending to fall to the lower end of the Superior habitat ranges with some specific sites lower than the range (Table 8). Our caution in interpreting the maritime comparison is that the study data are based on a single nest site. For example, all of the trees in the maritime nest patch were greater than 98 cm dbh and one was 273 cm dbh. Spacing of such large trees in the sample plot would translate to the patch having lower densities of > 50 cm dbh trees compared to a patch with more trees, but in the 50–100 cm dbh class.

DISCUSSION

Additional Nest Sites

Two nests located in the submaritime ecological subregion (CWH zone) were not included in our study. One was at a site reported in 1991 that could not be relocated and the other was newly located in 2010, after we had completed our analyses. The 1991 nest occurred in a large Douglas-fir chimney snag found at approximately 1200 m (L. Feldes, B.C. Ministry of Forest, Lands and Natural Resource Operations, pers. comm., Jul. 2004). The 2010 nest was in a 25 m tall, 75 cm dbh Douglas-fir chimney snag in a patch that contained large, approximately 20 m tall Douglas-fir snags (J. Gillis, B.C. Ministry of Forest, Lands and Natural Resource Operations, pers. comm., Feb. 2011). Tree species near the nest structure included Douglas-fir and western redcedar, with an understorey of shrub, herb, moss, and abundant coarse woody debris. Large trees in the stand had diameters greater than 150 cm dbh and heights of 40–50 m. The 1991 and 2010 structures and the 2010 nest site appear similar to those described in our study. However, the one noticeable difference is that the 1991 nest was at the highest recorded nest elevation in the submaritime and was closer to the elevation range that we report for continental nest sites.

TABLE 8 *Habitat variables used in Best Management Practices SOMP2 (Government of British Columbia 2010) that describe typical stands of "Superior" Spotted Owl habitat compared to those described from this study. Not applicable (NA) indicates the variable is not used to describe the attributes of the particular ecological subregion under SOMP2 and for the air photo random stand variables. Missing data are indicated by a horizontal score (-).*

	Ecological subregions					
	Maritime (wetter)			Submaritime (drier)		
	SOMP2	Patch Type		SOMP2	Patch Type	
		Nest	Random		Nest Average (SD) (range) n = 7	Random Average (SD) (range) n = 7
Attribute		n = 1	n = 1			
Crown closure (air photo)	> 70% (range 60–85%)	60	NA	> 70% (range 60–85%)	56.4 (6.3) (50–65)	NA
Canopy closure (ground)	> 70% (range 60–85%)	60	50	> 70% (range 60–85%)	47.9 (21.8) (10–70)	59.2 (12.4) (40–75)
Vertical complexity	3 canopy layers can include tall shrub	Moderately uniform	NA	3 canopy layers can include tall shrub	Moderately uniform to Very non-uniform	NA
Stand height (m)	> 30	46	NA	> 30	35.4 (3.6) (32–42)	NA
Trees > 30 cm dbh (stems/ha)	NA	117.1	137.5	average 240 (range 170–310)	144.8 (39.5) (97–219)	162.1 (68.0) (87–245)
Trees > 50 cm dbh (stems/ha)	average 200 (range 150–250)	66.2	81.5	approximately 100 (range 58–166)	85.9 (36.7) (66–168)	70.5 (18.6) (41–97)
Trees > 75 cm dbh (stems/ha)	approximately 100 (range 37–185)	40.7	35.7	NA[d]	42.9 (25.1) (10–87)	32.3 (25.5) (5–76)
Snags > 75 cm dbh[a] (stems/ha)	≥ 10	15.3	15.3	NA[d]	4.4 (5.4) (0–15)	0.8 (2.1) (0–5)
Snags >50 cm dbh[a] (stems/ha)	NA	25.5	25.5	≥ 10	9.5 (8.5) (0–25)	3.5 (4.2) (0–81)
Total shrub (%)	≥ 25%; patchy	55	-	≥ 25%; patchy	44.3 (14.3) (25–70)	49.2 (20.1) (25–80)

Continued on the next page

TABLE 8 *continued*

	Ecological subregions					
	Maritime (wetter)			Submaritime (drier)		
	SOMP2	Patch Type		SOMP2	Patch Type	
Attribute		Nest n = 1	Random n = 1		Nest Average (SD) (range) n = 7	Random Average (SD) (range) n = 7
Total vegetation[b] (%)	≥ 40%; patchy	> 55		≥ 40%; patchy	> 44.3 (14.3) (25–70)	> 49.2 (20.1) (25–80)
Total CWD (m^3/ha)	> 250 (range 50–1000)	–	–	> 75 (range 50–1000)	149.7 (128.4) (13–397)	315.7 (306.0) (11–824)
CWD > 30 cm dbh[c] (m^3/ha)		–	–		112.5 (106.9) (0–178)	279.0 (299.6) (0–772)
Tree species	• mixed conifer • preference for Douglas-fir • small hardwood component	• mixed conifer • no Douglas-fir • no hardwood component	NA	• mixed conifer • preference for Douglas-fir • small hardwood component	• 60–100% Douglas-fir • 86% hardwood component	NA

a SOMP2 is based on wildlife trees 2–7 with various defects (e.g., large cavities, broken tops, dwarf mistletoe infections, snag), whereas snags by definition would not likely include Wildlife Tree Class 2, which as live/unhealthy would be pooled with trees unless a substantial heath issue was easily determined.

b Total vegetation includes shrub plus vegetation < 0.15 m tall, but we did not account for overlap of the layers for total vegetation as per SOMP2. A minimum amount will include the total shrub amount.

c Submaritime CWD with a high component that is > 30 cm in diameter and > 5 m long.

d Trees and Snags > 75 cm dbh are captured in the Trees and Snags > 50-cm dbh classes.

Nesting Structures and Nest Habitat Selection

Given the limited sample size of nests located in British Columbia, we focus on interpreting our findings relative to those from U.S. studies. Spotted Owls in British Columbia exhibited flexibility in their use of different nest structure types and this is consistent with U.S. studies (Buchanan et al. 1993; Forsman and Giese 1997; LaHaye and Gutiérrez 1999; Sovern et al. 2011). We were unable to distinguish among a number of hypotheses that might explain this flexibility in use of nest structures, including whether it is due to (1) a varying supply of different types of nest structures over the owl's range (Forsman and Giese 1997; Hershey et al. 1998); (2) different structural types, such as closed cavities compared to open platforms providing different opportunities for the owl to nest in different kinds of ecosystems based on potential weather conditions, such as heavy rain, during breeding (Forsman and Giese 1997; Sovern et al. 2011); or (3) selection for nest sites occurring at scales other than the nest structure, such as the "patch-scale" examined in this study, where local habitat conditions surrounding a structure might affect attributes important for providing cover for thermoregulation (e.g., Barrows 1981; North et al. 2000) or antipredator strategies (e.g., Buchanan et al. 1995).

Most nest structures in British Columbia occurred in Douglas-fir trees, but most nest stands were also dominated by Douglas-fir trees. In the Washington Olympic Mountains, nests were found equally among western hemlock, Douglas-fir, and western redcedar trees (Forsman and Giese 1997). On the east slope of the Cascades, the majority of nests occurred in Douglas-fir, but mostly associated with dwarf mistletoe platforms (Buchanan et al. 1993, 1995; Sovern et al. 2011). Type of structure may be more important than tree species for affecting nest structure selection (Forsman and Giese 1997; Hershey et al. 1998). The British Columbia nest sample was predominantly (79%) cavity type structures. Side cavity nests were only located in the maritime-influenced subregions, in contrast to the two open stick nests in the drier continental, while top cavity nests were found across the owl range. In the case of Douglas-fir dwarf mistletoe platforms, although one nest platform was found in the submaritime, due to the limited occurrence of Douglas-fir dwarf mistletoe within the Spotted Owl range in British Columbia (Sutherland et al. 2007; Appendix 3) it appears a less likely source for platforms than has been found in the drier U.S. eastern range (Buchanan et al. 1993, 1995). United States studies revealed that types of structures used vary across the owl range with greater use of top cavities and platforms with continentality (Forsman et al. 1984; Buchanan et al. 1993, 1995; Forsman and Giese 1997). In addition, Forsman and Giese (1997) suggested a possible latitudinal influence on used types of nest structures, where the proportions of nests in dead trees ranged from 4 to 23% south to north, respectively, in the United States. Our northerly sample is consistent with this trend of more nest structures in dead trees (i.e., 43%).

Cavity nests, in this study, were associated with larger-diameter trees and snags (i.e., 97.8 cm dbh average diameter in this study). Cavity nest trees from the Washington Olympic Mountains and western Oregon averaged between 130 and 140 cm dbh (Forsman and Giese 1997; Hershey et al. 1998). Larger-diameter trees are needed to provide cavities of sufficient size for nesting, but large diameters may also be correlated with the lengthy period over which such cavities are recruited by processes of damage, disturbance, and decay. In contrast, the trees with open platform nest structures in our study, as shown for U.S. studies, can have smaller diameters (Forsman et al. 1984; Buchanan et al. 1993; Forsman and Giese 1997), possibly due to type of structure (i.e.,

platform not cavity). These smaller diameters could also be due to limited availability of trees of larger diameter—as shown in the drier continental by our study or in younger stands (reviewed in Hershey et al. 1998). Heights of nest structures varied with type of structure, but most nests were located below or within the lower overstorey, and height might simply reflect structure availability (Forsman and Giese 1997).

Broad ecosystems that overlap the Spotted Owl range in British Columbia transition from coastal wetter maritime influenced forests to drier continental forests. Our analyses confirmed some differences in forest structure of stands between the submaritime and continental (i.e., lower tree densities and less moss cover, but greater cover of fine coarse woody debris in the continental). These subregional differences did not appear to translate to differences at finer scales of selectivity testing within nest stands or the local landscape (Buchanan and Irwin 1998). At the finer patch-level scale of testing, there was some evidence that nest sites selected within the nest stand had particular structural characteristics that differed from elsewhere within the stand, including that nest patches had significantly higher densities of small trees (< 10 cm dbh) and lower densities of mid-size snags (30–50 cm dbh). Higher densities of small trees could provide more cover around a nest structure, helping to conceal the nest and movements or roosting by the adults around the nest as a possible habitat-mediated, anti-predator strategy (Buchanan et al. 1995). The use of patches with fewer mid-sized snags is difficult to interpret due to our small sample size. One possibility is that patches with higher densities of larger trees and snags may have lower densities of mid-sized stems due to self-thinning over time or as an artifact of disturbance history such as fire in drier sites. Our data suggest a possible trend, albeit non-significant, for greater densities of larger snags (> 50 cm dbh) in these nest patches with few mid-sized snags (Table 4). Large snags may simply represent patches having higher potential to provide nest structures; alternately, in some studies, snags (and/or coarse woody debris) are indicative of a potential to support higher densities of prey (Hershey et al. 1998).

Only one air photo attribute differentiated the nest stand from other potential stands (based on age > 140 years) adjacent to it in the local landscape. Nest stands had taller trees. Stands within the local landscape that have taller trees also likely represent older and structurally complex habitats, thus having better potential for providing nest structures, and nesting and foraging habitat (Forsman et al. 1984; Buchanan et al. 1995; Forsman and Giese 1997; Hershey et al. 1998; reviewed in Chutter et al. 2004). Further support of the importance of structurally complex forest for nest sites might be inferred for those nest stands that had a mix of structural stages, because the nest sites rather than the random sites tended to occur in the older patches available in these heterogeneous stands.

Elevations of nest stands differed, with stands occurring at higher elevations as ecosystems changed from the maritime to the continental; but as elsewhere, nest stands did not occur in the subalpine (Hershey et al. 1998). Although aspect of nest stands widely varied (i.e., 10–290°), indications were that aspect was non-random with most structures on slopes facing, at least in part, to the south and/or east, which are warmer aspects. Buchanan et al. (1993) found preference for east-southeast and southeast nest exposures and suggested that these preferences may reflect other factors, including prevailing storm patterns or optimal thermoregulation. We are cautious in overly interpreting relationships with aspect both due to the variety of differing

findings from elsewhere (e.g., Hershey et al. 1998) and due to study limitations (see below).

Study Limitations

Our Spotted Owl nest sample is non-random and small, thus we are cautious in overly interpreting our results for management and rely on identifying consistencies in our findings with studies elsewhere on the Spotted Owl. Nests were located incidental to inventories that followed different methods and objectives. However, 13 of the 14 nests in our sample were distributed across the submaritime and continental, so they did represent the variety of ecosystem variants and forest types occupied by Spotted Owls in British Columbia. The maritime was represented by only one nest. Potential bias related to location was controlled by limiting which attributes were compared in tests and the scale of testing (i.e., patch-level within the stand and stand-level within the local landscape), as well as using paired tests within locations. Using paired randomization tests also helped control for the small sample, but in turn small samples meant that randomization tests had fewer random pair combinations, thus low power to detect significant differences. Our limited findings of few significant differences are reasonable if landscape habitat selectivity by Spotted Owls supersedes local stand or patch-level selectivity, thus constraining finer scales of habitat selection (hierarchical habitat selection; Manly et al. 2002).

Management Implications - SOMP2

Owl management areas within the Squamish and Chilliwack Forest Districts overlap the maritime and submaritime ecological subregions and, depending on current legal designation of these areas, acceptable operational practices are defined under General Wildlife Measures (GWM), (B.C. Ministry of Environment 2011) and or Best Management Practices (BMP) (Province of British Columbia 2010).[1] Two approaches are enabled: Habitat Enhancement Practices (HEP) in Long-term Owl Habitat Areas (LTOHA) and Harvest With Retention (HWR) in Managed Future Habitat Areas (MFHA). Long-term Owl Habitat Areas represent current core habitats for the Spotted Owl, and Habitat Enhancement Practices are therefore applied to create or enhance the recruitment of attributes associated with superior suitability for nesting and foraging. Managed Future Habitat Areas are those areas that may potentially provide future habitat if landscape habitat planning or owl use requires shifting the area into a Long-term Owl Habitat Area. Harvest With Retention is used to promote structural retention in current Managed Future Habitat Areas to reduce recruitment lags for desirable attributes such as large trees, snags, and downed wood associated with "Superior" owl habitat (Government of British Columbia 2010).

The nest sample in our study was considered with other information from U.S. studies in the development of the "Superior" habitat definition and this is demonstrated by our comparison of habitat attributes (Table 8; Government of British Columbia 2010). Nesting habitats in British Columbia based on the patch and stand metrics sampled in our study are characterized by structural complexity in the form of large trees, large snags, a shrub layer, and coarse woody debris, as typically described for other regions within the Spotted Owl's distribution (Forsman et al. 1984; Gutiérrez et al. 1995).

One of the variables most difficult to interpret as used in SOMP2 relative to the nest patches was overstorey crown or canopy closure. High overstorey

1 GWMs apply to the legally designated Wildlife Habitat Areas in the Chilliwack Forest District. BMPs presently apply in the Squamish Forest District, and will be replaced with GWMs when the WHAs are legally established. GWMs must be adhered to, while BMPs are not legally enforceable.

canopy closure is thought to be important at the nest sites for providing protection at the nest site to maintain microclimate (North et al. 2000) or from predators (Buchanan et al. 1995); and it is also characteristic of older forests (Hershey et al. 1998). Crown closure, based on air photo interpretation for our study, was within the lower suitability range of other studies and that recommended within SOMP2. Ground estimates of canopy closure for the nest patch above the nest structure in our study varied, but were also typically in the lower range of the SOMP2 recommendation. Estimates from our study may have been lower for canopy closure of the patch because some of the chimney snag nest structures had created canopy gaps with breakage thus producing an open area above the snag, while other nest structures were located at the edge of openings (e.g., talus; and these particular patches would have lower coverage). Forsman and Giese (1997) reported ranges of 30–95% canopy closure with low coverage due to adjacency of the nest to natural openings. Hershey et al. (1998) reported higher canopy closures (approximate average 77% from theirs and other studies), but estimate methods (e.g., densitometer, hemispherical camera) varied with studies and differed from the ocular method we followed in Luttmerding et al. (editors and compilers, 1990). Observer and method differences may affect canopy closure estimates, making them incomparable (Bunnell and Vales 1990; Korhonen et al. 2006). Consideration needs to be given to both the method used to obtain crown closure / canopy estimates and the area over which the estimate was obtained when assessing this metric relative to the estimate range provided in SOMP2.

CONCLUSIONS

Although Spotted Owls appear able to exploit a relatively broad range of habitat conditions within different vegetation associations (i.e., ecological subregions), some consistent features characterize these habitats (Gutiérrez et al. 1995; Everett et al. 1997; Buchanan and Irwin 1998). Owls need particular types of structures for nesting, and availability of these structures varies among different ecosystem types, likely a reflection of disturbance history, site productivity, disease, and possibly the presence of other species that create structures used by the owls. Some nest structures (e.g., cavities) can have a long expected lifespan (e.g., 120 years) and are often reused, although not necessarily during subsequent nesting years (Forsman and Giese 1997). Therefore, provisioning of habitat over the long term requires management of stands wherein recruitment potential of suitable structures is sustained over extended periods and/or planned recruitment of stands is designed to produce suitable structures in a shorter timeframe (e.g., forests that are managed to produce target conditions). Given the processes by which nest structures and patches or stands typical of having these structures are created, retention measures for SOMP2 will be beneficial to meet objectives. Using the three ecological subregions appears to help capture the transition in potential supply of different structural types. Based on similarities between nest sites in British Columbia and the United States, extrapolating information from studies in the U.S. portion of the Spotted Owl range appears appropriate if ecological variation (including latitudinal influence) is taken into consideration.

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APPENDIX 1

TABLE A1.1 *Attribute classification adapted from Waterhouse et al. (2002) for describing polygons with Spotted Owl nest sites and random polygons within the Landscape Cover Classification Scheme following Vegetation Resource Inventory Standards (2001)*

Attribute	Definition
Crown Closure	Percentage estimate of the vertical projection of tree crowns upon the ground by each tree layer identified.
Basal Area	Total cross-sectional area (m^2/ha), at breast height, of all living trees visible to the photo interpreter in the dominant, co-dominant, and high intermediate crown positions for each tree layer in the polygon.
Stand Height	Average height (m), weighted by basal area, of the dominant, co-dominant, and high intermediate trees for the leading and second species of each tree layer identified.
Vertical Complexity	Subjective classification that describes uniformity of the forest canopy by estimating the total difference in height of leading species and average tree layer height, describing occurrence of canopy gaps and past or recent disturbances, and stocking patterns. • Very uniform. < 11% height difference, no evidence of canopy gaps or recent disturbance. • Uniform. 11–20% height difference, few canopy gaps may be visible, and little or no evidence of recent disturbance. • Moderately uniform. 21–30% height difference, some canopy gaps may be visible, and there may be evidence of past disturbance, stocking may be somewhat patchy or irregular. • Non-uniform. 31–40% height difference, canopy gaps often visible (due to past disturbance), stocking typically patchy or irregular. • Very non-uniform. > 40% difference between the height of the leading species and the average tree layer height. Stocking is typically very patchy or irregular.